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I Sea You: A comparison of eastern and western sea lion population recovery and natality

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I Sea You:

A comparison of eastern and western sea lion population recovery and natality

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University of Portland Senior Honors Research Project

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Abstract

Since the 1970's, Steller sea lion (*Eumetopias jubatus*) populations have decreased in the western distinct population segment (DPS) but not in the eastern DPS despite historical culling of eastern stock. Competition for fish with fisheries has led to a nutrient lacking diet, affecting reproductive success and natality. Anthropogenic threats such as heavy metal contamination and chemical toxins can cause physiological damages, decreasing reproductive success. The use of the ocean for human gain, and disrespect of the ecosystems within it should be stopped from progressing into further destruction so that the ocean and the threated populations of Steller sea lions within it can recover.

Eumetopias jubatus is the Steller sea lion, one of the sixteen species that comprise the Otariidae family, distinctive from the Phocidae seals by the presence of ears (Chivers, 2018). Steller sea lions are the largest of the otariid species, with sexually dimorphic characteristics most predominantly in size, with males spanning 11 feet and weighing up to 2,200 lbs., over three times as large as adult females weighing up to 700 lbs. and reaching 9.5 feet in length (Lower Columbia Fish Recovery Board, 2004; NOAA Fisheries a). Of both sexes, their coat varies from a light tawny color to dark brown that sheds every year, flippers are hairless and black, and long-light colored whiskers, called vibrissae, protrude from their muzzle are used to sense prey underwater where they "use broad, long front flippers to propel themselves and are highly maneuverable" (NOAA Fisheries a). On land, unlike "true" seals such as harbor seals in the Pacific, Steller sea lions can be found on rocky cliffs, where they have climbed using hind flippers that can rotate forward for walking (NOAA Fisheries a).

At sea, Steller sea lions forage for food at night, hunting fish species including but not limited to Pacific cod, rock sole, rockfish, salmon, and steelhead, and both squid and octopus (NOAA Fisheries; Harrison, 2018). Both pelagic and benthic zones of the ocean are fished, and prey can vary between the two along with season (Lower Columbia Fish Recovery Board, 2004). Nonbreeding females have been observed feeding at both pelagic and benthic zones, while breeding females tend to remain in the benthic zone closer to the rookery (NOAA Fisheries a). Males tend to disperse away from rookeries after breading season, although they have no migratory season (Lower Columbia Fish Recovery Board, 2004).

Steller sea lions occupy the Pacific Ocean coast lines, ranging from populations that cohabit Californian coasts with California sea lions, to populations extending into Russian and Japanese waters shared with northern fur seals (Lower Columbia Fish Recovery Board, 2004).

Terrestrial sites are used by both breeding and nonbreeding Steller sea lions used for resting, mating, molting, with rookeries being primarily used during breeding season, but can be used all year in conjunction with haulouts (NOAA Fisheries, 2018). Social creatures, during the breading season from May to June, large group overlap on rookeries as pups learn to dive and swim nearby (NOAA Fisheries a). Over 472 haulouts of beaches, ledges, and rocky reefs along the United States coast have been mapped and named by the NOAA Alaska Fisheries Science Center National Marine Mammal Laboratory (NMML) Alaska Ecosystem Program (AEP) to be used for data collection, production, and publication (NOAA Fisheries, 2018).

Within the United States population of Steller sea lions, two stocks have been differentiated due to Loughlin's (1997) analysis of distributional data, population response data, phenotypic differences in pup length, and genetic differences in mitochondrial DNA. The eastern distinct population segment (DPS) consists of Steller sea lions born east of Cape Suckling, Alaska (144°W) and the western DPS of those born west of Cape Suckling (Loughlin) (Fig. 1). Intermixing may occur while foraging, or during the movement of juvenile and adult males, but females consistently return to natal or

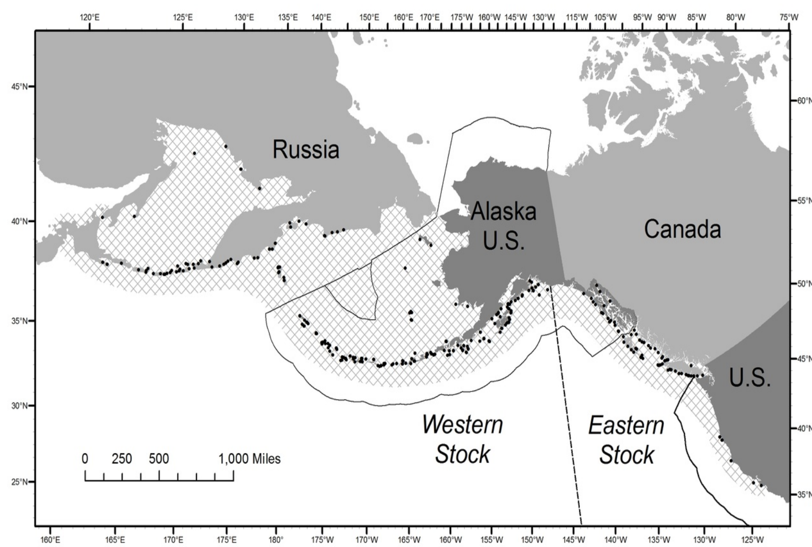

Figure 1. Steller sea lion range (crosshatched area) and haulouts and rookeries (points) in the North Pacific. Black solid line encompasses the U.S. Exclusive Economic Zone, and the black dashed line at 144°W differentiates stock boundaries (NOAA Fisheries b).

nearby rookeries for reproduction and care of pups, keeping the two stocks separate (Muto et al., 2018) until the 1990s when two mixed-stock rookeries of breeding females between Prince William Sound and Southeast Alaska were observed (Jemison, 2013). For the western DPS, thirty-nine rookeries are located in Alaska, and over 250 haulouts are used all year along the Alaskan coast (Trites and Larkin, 1996). The eastern DPS reaches as far down as California and within the past decade Steller sea lions have been reported inland within the Columbia River Basin (Harrison, 2018).

The western DPS have historically been of importance to Indigenous People of Alaska with remains being found in Aleutian Island sites dating back 4,000 b.p. (before present) as they replaced walrus populations (Haynes and Mishler, 1991). Although no total population numbers were ever recorded, when Russians exploited Alaskan coasts for fur seals in the late 1780s, Russian Orthodox missionary Ivan Veniaminov reported 2,000 sea lions being hunted annually by Aleuts that had been relocated to St. George in the Probilof Islands, where they were then used for clothing, and other subsistence uses (Haynes and Mischler, 1991). In the 1950s there was an estimated 250,000 Steller sea lions in the Gulf of Alaska, and numbers increased until 1975 when populations reached 282,000 in number (Trites and Larkin, 1996). In contrast "the eastern population of Steller sea lions (California to southeast Alaska) was historically much smaller than the western population, accounting for roughly 10% of total abundance between the 1950s and 1970s "(COSEWIC, 2003) (Fig. 2). Numbers recorded by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) estimated populations as small as 14,000 animals in British Columbia, Canada between 1913-16 (2003). Between 1913 and 1969 in Canada, Steller sea lions were hunted as part of a predator-control program to protect salmon

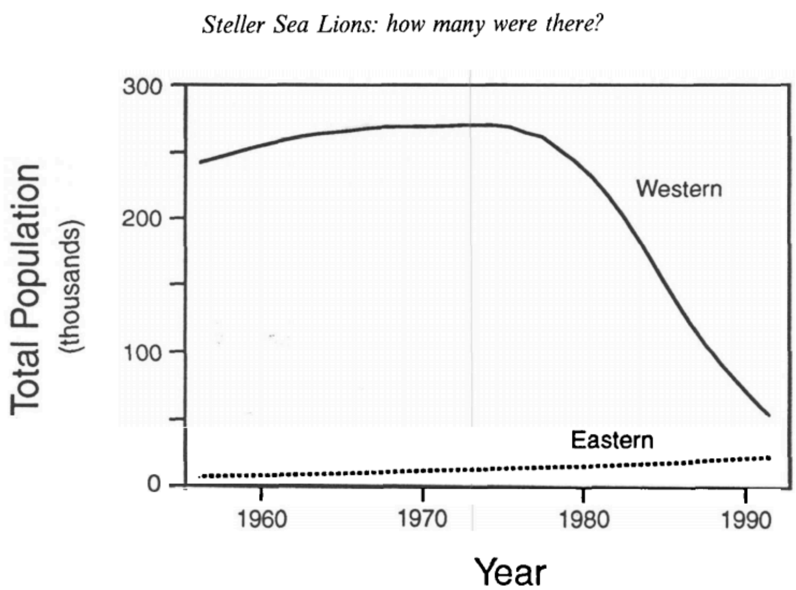

Figure 2. Estimated Steller sea lion populations in both eastern and western stocks of Alaska between 1960 and 1990 (Trites and Larkin, 1996).

populations, along with unrecorded numbers killed during World War II while the Canadian air force and navy practiced bombing (COSEWIC, 2003). By the late 1970's the eastern population was as low as 18,000 animals (Marine Mammal Center b).

In the late 1970s the western DPS decreased dramatically. For unexplained reasons the total population of Steller sea lions decreased by approximately five percent each year (Trites and Larkin, 1996). Regionally this varied, and the Gulf of Alaska and Aleutian Islands had the most noticeable drop in population, as the region had held seventy-four percent of the worldwide population of Steller sea lions in 1977, and decreased to fifty-six percent of the worldwide population twelve years later in 1989 (National Park Service, 2015). Steller sea lions were already protected under the Marine Mammal Protection Act (MMPA) as of 1972, in which people may not "harass, feed, hunt, capture or kill any marine mammal" (Marine Mammal Center a) without a permit, to maintain the marine ecosystem. Despite this, the National Marine

Fisheries Service (NMFS) listed the Steller sea lion as a threatened species under the Endangered Species Act (ESA) of 1973 in 1990, citing "the number of Steller (northern) sea lions (*Eumetopias jubatus*) observed on certain rookeries in Alaska declined by 63% since 1985 and by 82% since 1960. The declines are spreading to previously stable areas and accelerating." (NMFS, 1990). In the Federal Register, NMFS poses multiple factors that may have influenced the decline including "the present or threatened destruction, modification, or curtailment of its habitat or range," "overutilization for commercial, recreational, scientific, or educational purposes," "disease or predation," "the inadequacy of existing regulatory mechanisms," and "other natural or manmade factors affecting its continued existence" (1990). Of these reasons two main theories were put forth to explain the decline: 1) a warming trend in the Gulf of Alaska and the Bering Sea that caused fish of the clupeiforme family, such as herring, a major part of the Steller sea lion's diet, to decrease in population and be overtaken by cod, and pollock, fish less nutritious to the Steller sea lions, and 2) competition with fishermen for available resources (National Park Service, 2015). Three-mile buffer zones (Fig. 3) were set around rookeries, and during winter roe pollock

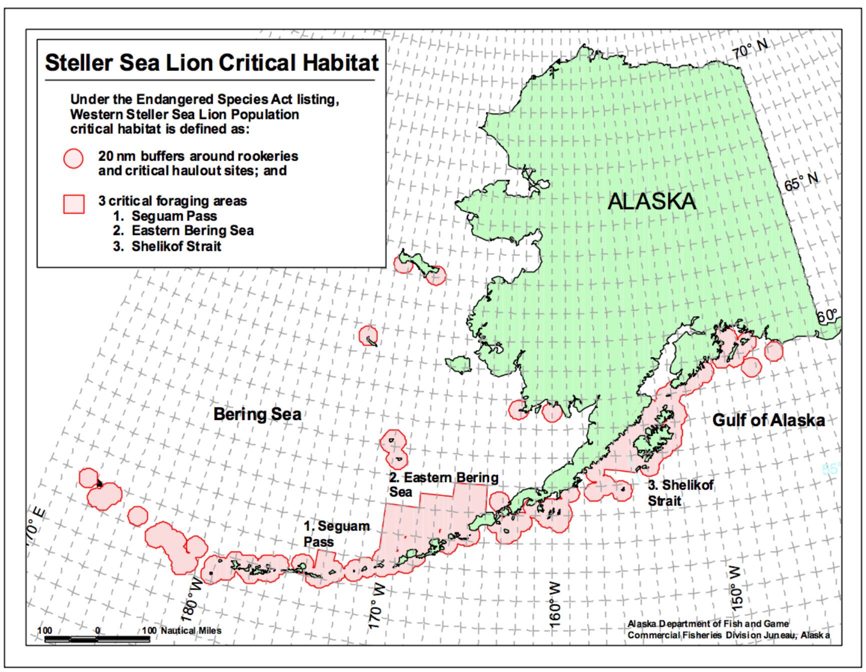

Figure 3. Steller sea lion critical habitat and no trawl zones as defined by NMFS (Kruse et al., 2000)

season, twenty-mile no trawl zones were set around six rookeries to allow “sea lions more available pollock at a time when it would be most nutritionally important for them, when female sea lions are pregnant and when the pollock was rich with roe” (National Park Service, 2015). By 1997, with much research focused on Steller sea lion populations, Loughlin (1997) proposed the idea of the two geographically differentiated stocks, the eastern and western DPS and in 1997 the NMFS reclassified Steller sea lions as two distinct populations in which the eastern DPS retained its threatened listing under the ESA and the western DPS was elevated to endangered due to its lack of recovery and threat of extinction in a significant part of its range (NOAA). Don Calkins, researcher at the Alaska SeaLife Center in Seward Alaska theorizes that nutritional stress was the major cause of the decline, as competition with fisheries and potential contaminant “reduced prey availability … causing a nutritional problem that decreases the fitness of young animals” (National Park Services, 2015) rather than anthropogenic threats such as “(i) mortality incidental to commercial fishing; (ii) legal and illegal shooting; (iii) commercial hunts of Steller sea lions; (iv) subsistence hunting; and (v) mortality incidental to research” (Atkinson et al., 2008)..

The western DPS continued to decline in population through the end of the 20th century, although decreasing in rate leading to a low of 50,000 animals in 2000 (NMFS, 2008). Evidence of reproductive failure was found in samples taken in the Gulf of Alaska:

> 97% of sexually mature females in the western DPS were pregnant in early gestation. However, the percentage of females that carried their pregnancy to late gestation fell to 67% during the 1970s and to 55% in the 1980s indicating that a considerable amount of intrauterine mortality and/or premature births occurred after implantation. (NMFS, 2008)

Lactating females had decreased chances of pregnancy, from sixty-three percent to only thirty percent, between the 1970s and 1980s (Pitcher et al. 1998). Currently bioenergetics of Steller sea lions are being studied by Markus Horning at the Alaska SeaLife Center to understand how a decrease in food or food of a lesser nutritional quality plays a role in the maternal investment during both pregnancy and lactation (Alaska SeaLife Center).

> This study will determine the costs of gestation, lactation, and growth by measuring the metabolism, energy intake, and morphology of pregnant and lactating Steller sea lions and their pups. The resulting information will inform bioenergetic models that will help define the potential effects of changes in the environment on Steller sea lion population trajectories: (Alaska SeaLife Center)

Coupled with a decrease in survival of juvenile Steller sea lions by York (1994) of five percent a year, western populations remained low into 2017 (Fig. 4). 2000 to 2004 saw a twelve percent

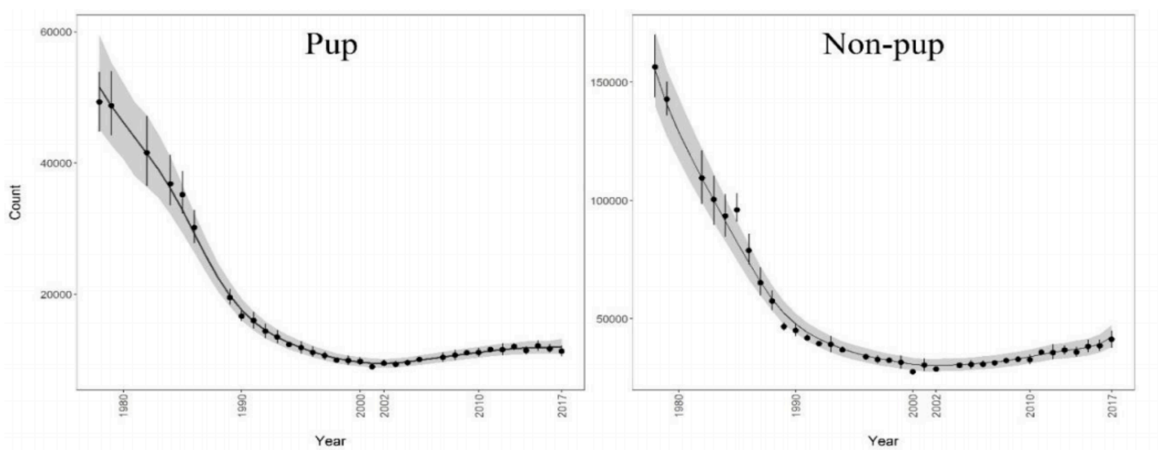

Figure 4. Realized (points with lines of 95% credible interval) and predicted (black line with gray 95% credible interval) counts of western Steller sea lion pups (left) and non-pups (right) in Alaska from 1978 to 2017. (Muto et al., 2018)

increase in non-pup populations of the western DPS, although not spread evenly as numbers continued to decline in the Gulf of Alaska and the western Aleutian Islands, but by 2005 the western population had risen to an estimated 61,000 sea lions (NMFS, 2008). In contrast, the eastern DPS has increased in population by an average of 3.2% for both pups and non-pups each year (Fig. 5), and in conjunction with the decrease in western DPS, now accounted for over fifty percent of worldwide Steller sea lion population (NMFS, 2008).

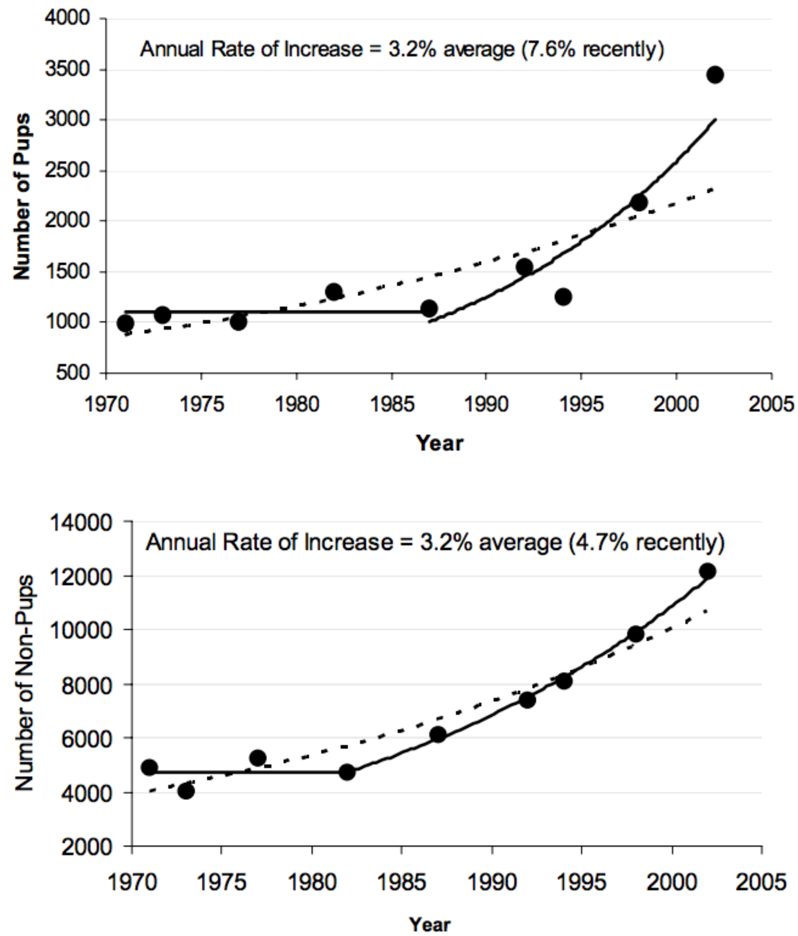

Figure 5. Population trends of pups (top) and non-pups (bottom) of eastern Steller sea lions. Dashed lines are overall average trends, solid lines allow for a change in the population growth rate (COSEWIC, 2003)

Steller sea lions breed annually, with variations in timing. Trends in variables such as whether a pup had been birthed and cared for the previous year, maternal age, and sex and mass of the pup were analyzed along with dates of birth during a six-year study to determine factors that may be able to better predict long term trends of populations so that better recovery and conservation plans can be made (Maniscalco and Parker, 2018). Between 2005 and 2016, at a western DPS rookery on Chiswell Island in the Gulf of Alaska 152 adult females were tracked in accordance with the Alaska SeaLife Center's Institutional Animal Care and Use Committee Protocol No. R16-02-01 and the National Marine Fisheries Service Permit Nos. 18438 by use to six remotely operated cameras on the island, and identification systems such as hot iron branding, tags, or physical markings. The sea lions were viewed four to ten times daily, where birth time could be observed and known within an eight-hour range. At the end of pupping seasons in 2005, 2007, 2008, 2010, 2011, and 2016 pups were captured to record physical measurements such as age, sex, weight, and length and to give a mark for later identification. Birth mass was then estimated through linear regressions of capture mass versus age. Maternal age was known of only seven percent of the identified females, and so maternal experience (observation year minus the year of first known birth) was used to estimate the age of the sampled sea lions, ranging from four to twenty years old. If a pup had been birthed the year prior and survived over a month so that the mother sustained a lactation period of a year she was scored a 1. If a pup was not born or did not survive past a month, the mother was scored a 0. Pups were observed being born as early as May 5 to July 31, with a mediate date of June 12. A linear effect on birth, parturition, date based on maternal age, survival of a previous year's pup, and mass and sex of the pup was observed. This study conducted on a western Steller sea lion population is comparable to a study of eastern Steller sea lions and parturition date (Hastings and Jeminson, 2016), in which maternal age a large effect on parturition (Fig. 6) (Maniscalco and

Parker, 2018). Of the variables, the largest single effect was due to the presence or absence of a pup born the previous year that had been nursed, which lead to a delay of 2.4 days in parturition

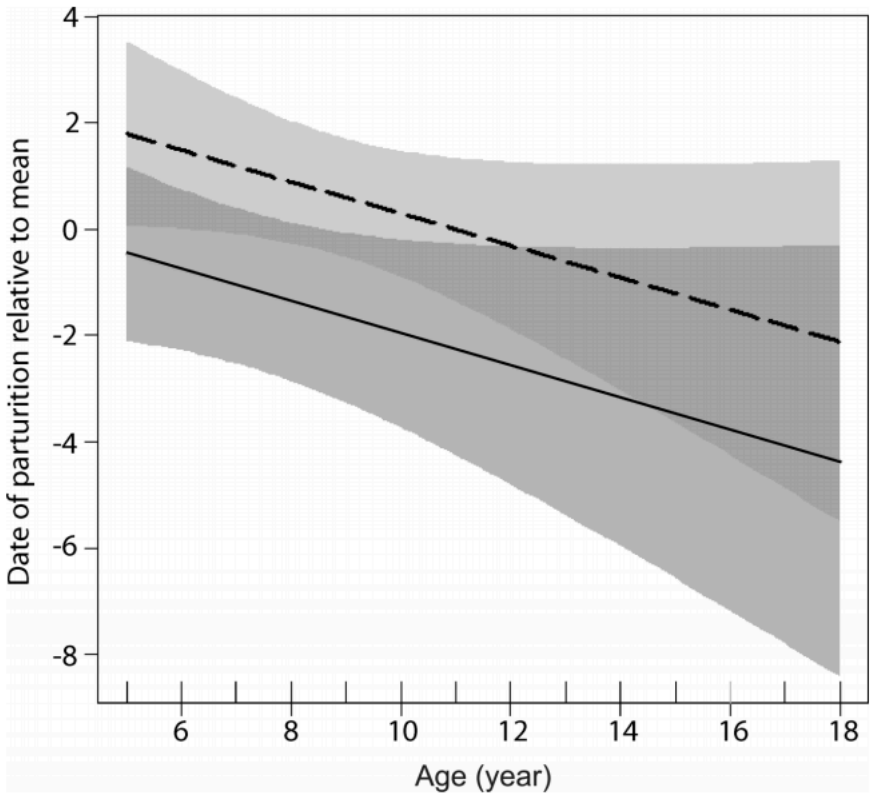

Figure 6. Maternal age of female western Steller sea lions who had given birth the year prior (solid line) and who had not given birth the year prior (dashed line) negatively linearly correlated with date of parturition relative to a median date of June 12.

the following year. Older, larger females who had previous experience navigating the rookery and knowledge of where to find food birthed larger offspring earlier in the pupping season, who had increased chances of survival due to their larger size, and access to more plentiful resources (Bender, 2019). The Steller sea lion recovery plan aims to use “biological principles and ecological understanding” (Steller Sea Lion Recovery Team, 1992) to promote growth within the western Steller sea lion population. Attention should be paid to the timing of births so that human interaction and disturbances can be decreased, and more accurate long term population models can be created for the use of limiting fishing limits so that ecological balance can be maintained between numbers of predator and prey.

Along with competing with fisheries, leading Steller sea lions to consume fish of a lower quality that may negatively affect reproductive success and natality, chemical pollutants are another anthropogenic effect affecting pups and juveniles. Through the burning of coal and mining of metal, humans have increased atmospheric mercury levels since 1850 by an estimated factor of 7.5 as compared to levels 3000 years ago (Zhang et al., 2014). Mercury in the atmosphere is cycled into the ocean where it is methylated producing monomethymercury, a neurotoxin that accumulates in marine fish and all animals that consume them (Zhang et al., 2014). At rockeries on Agattu Island, Bogoslof Island, and Ugamak Island in the Aleutian Islands, natal hair samples that had been grown *in utero*, called lanugo, were collected from western Steller sea lion pups (Rea et al., 2013). The lanugo provides a record of the mercury levels the fetus had been exposed to through the mother's diet of fish, squid, and octopuses. Blood samples were also taken from pups ranging from 5 days to 6 weeks old to be used as a comparison against the lanugo sample. For fish eating mammals, such as otters, seals, and sea lions, a threshold of 20 μg/g in hair had been set by D.R. Thompson (1996) through a collection of laboratory studies that measured levels sufficient to cause mercury intoxication and in some cases death. In the samples collected by Rae (2013), lanugo samples produced a median level of mercury concentration that was higher than samples previously measured in a 2012 Southeast Alaskan study (Castellini et al.) Seven of the thirty-four pups samples were found to have lanugo mercury levels of over 20 μg/g, and while the whole blood mercury levels that would reflect both mercury levels acquired *in utero* through fetal-maternal nutrient exchanges and through the acquisition of mercury through a diet of milk, were lower they were strongly correlated to the levels found in lanugo (Rea et al., 2013). Of fifteen pups sampled at Agattu Island, where the range of lanugo levels were wider than at other rookeries, three fell within a range of mercury intoxication that have been seen to produce neurological effects (Fig. 7) and negative reproductive affects in other fish eating mammals. In comparison to a study of mercury levels in mother and pup northern fur seals, where maternal hair had a higher concentration than pups (Beckmen et al., 2002), it is expected "that mercury exposure of the Steller sea lion dam was elevated enough to achieve these relatively high concentrations in fetal hair, but was not lethal to the dam or the fetus" (Rea et al., 2013). Along with mercury levels, carbon and nitrogen isotope levels were measured in samples of pup vibrissae. The ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes correlated to pup mercury levels, suggesting that fetal levels of mercury increased when mothers fed on diet that contained prey of a higher tropic level such as salmon or steelhead as opposed to herring. As food sources change for female Steller sea lions of breeding maturity, and mercury increase by ninety percent in Arctic

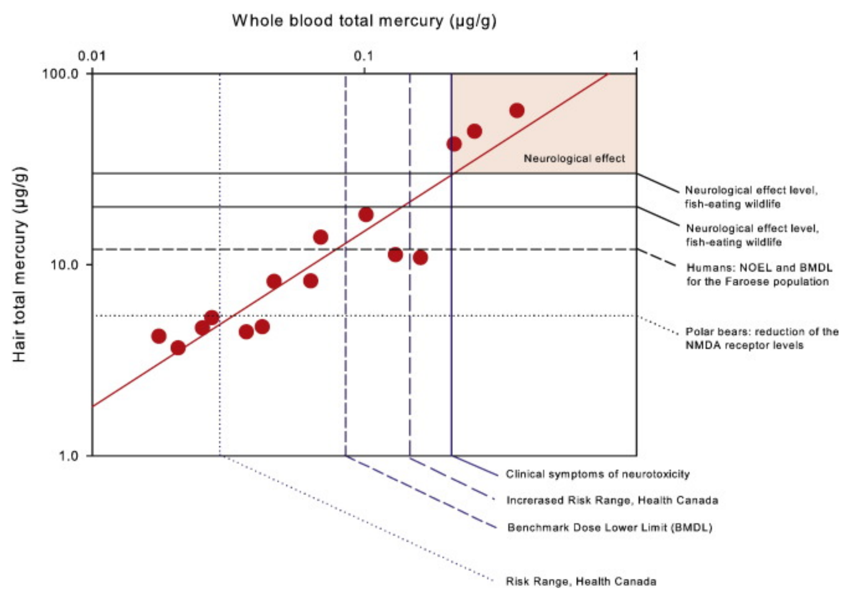

Figure 7. Relationship of whole blood total mercury concentration and mercury concentration of lanugo in fifteen western Steller sea lion pups sampled from Agattu Island.

wildlife over the past 150 years, human actions and pollutants must be considered as a reason the western DPS of Steller sea lions has failed to recover and natality continues to decrease, as fetuses are exposed to levels of metals that delay development reducing survival rates.

From the 1930's to the 1980s, polychlorinated biphenyls (PCBs) were used in the production of plastic products, pesticides, and flame retardants before being discontinued due to the public health and wildlife threats (Wang et al., 2011). In both humans and other mammals, PCBs have been shown to react with and disrupt the endocrine system (Quinete et al., 2014) and in wildlife populations, including marine mammals, have affects such as developmental defects and malformations *in utero*, deterioration of the immune system, and reproductive failure (Wang et al., 2011). Chemical pollutants, as opposed to heavy metal contaminants such as mercury, have risks such as "teratogenesis, uterine blockages, spontaneous abortion, and low birth weight of pups" (Want et al., 2011). In the western Steller sea lion populations where natality is low in comparison to the eastern population, studies have previously found PCBs in both blubber and liver tissue. Female Steller sea lion placental samples, and male blubber, kidney, and liver samples were collected from western DPS ranging from the Aleutian Islands to Prince William Sound. Samples were analyzed using Saturn GC-MS workstation v5.4 software program and identified as specific PCBs through a comparison to standard retention times of known PCBs. Of the samples taken from male sea lions, fifty-one PCBs were found in blubber samples, sixty-six in liver samples, and thirty-eight in kidney samples, for respective concentrations of 0.5, 3.2, and 2.4 μg/g. Of the female placental sample, thirty-five PCBs were identified with a median concentration of 1.2 μg/g. Of the PCBs identified in all the samples, four were dioxin-like in structure, a group of toxic chemicals that can cause cancer, reproductive and developmental problems, and weakening of the immune system: PCB 81, PCB 105, PCB 118, and PCB 157

(EPA; Wang et al., 2011). Toxic equivalents (TEQ) were calculated for all dioxin-like PCBs (Table 1). Although female placental samples had less of a PCB concentration than the other sampled tissues, transferal of PCBs from mother to fetus can be assumed and a higher mean TEQ could lead to more toxic effects that disrupt reproduction and development, decreasing natality of a population. Male liver tissue samples “were within a range known to cause physiological effects” (Wang et al., 2011) another reason why pup and juvenile populations of western Steller sea lions may not be recovering as eastern populations have. Solutions such as transferring PCB-

Table 1. Mean toxic equivalents (TEQ) of PCBs 81, 105, 118, and 157 that were found to be dioxin-like in structure in male blubber,

Sample type	Concentration means and ranges (ng/g lw)								TEQ means and ranges[a]	
	PCB 81		PCB 105		PCB 118		PCB 157			
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Blubber	1.0	nd[b]–3.6	1.2	nd–4.9	5.2	nd–8.7	nd	nd	7.4	1.2–14.4
Liver	nd	nd	1.7	1.0–2.8	0.5	nd–1.5	2.5	nd–6.1	4.7	1.6–8.9
Kidney	nd	nd	0.6	nd–2.2	2.0	nd–4.2	nd	nd	2.6	nd–5.3
Placenta	2.24	nd–13.7	0.25	nd–1.8	5.3	1.5–10.3	nd	nd	8.0	1.5–17.9

degrading bacteria to contaminated soil have found to remove seventy percent of PCB levels in soil over several months but no widespread water treatment that may decrease PCB levels in marine habitats and organisms, for anything other than drinking water in cities has been proposed (Oak Ridge National Laboratory, 1996; Public Health Division, 2015).

Aerial surveys of both eastern and western DPS have been conducted since 2010 by the NMFS to “assess abundance, trends, and distribution of Steller sea lions in Alaska” (NOAA Fisheries, 2010). Pup production between 2010 and 2018 has varied between regions of the western DPS, with some rookeries ceasing to produce pups, some staying stable, and some increasing (NOAA Fisheries, 2018). Between 2002 and 2018, the Samalga Pass (Fig. 8) has acted as a divider between rookeries of the western DPS, with those east of the pass generally increasing in pup and non-pup counts, and those went of the pass decreasing in pup and non-pup

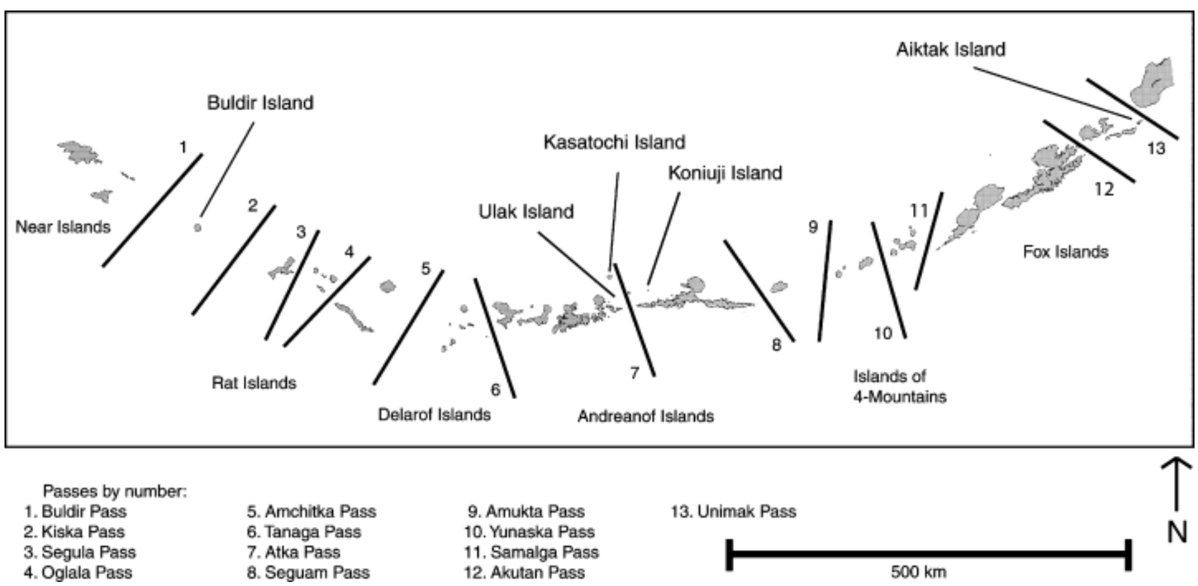

Figure 8. Passes of the Aleutian Islands, in which Samalga Pass (11) acts as a divider between increasing and decreasing western Steller sea lion rookery counts (Byrd et al., 2005)

counts. Of the eastern DPS in 2013 it was delisted and removed from the List of Endangered and Threatened Wildlife after a thirty-year period of annual average three percent increase in population that lead to an estimated 70,174 animals in 2010 (NOAA, 2013). To this date the western DPS remains listed as endangered species due to the minimum non-pup population size of 42,315 found in after a decrease in non-pup numbers in the Gulf of Alaska (Alaska Center for Conservation Science, 2018).

Despite extensive numerical differences before the 1970s, today's populations of the western DPS and eastern DPS are almost equal. While the eastern DPS now faces issues such as movement into the Columbia River Basin up to the Bonneville Dam where it preys on endangered species of salmon and steelheads (NOAA Fisheries c), it is no longer listed under the ESA. For the western DPS, it continues to be listed as endangered, and a large reason continues to be human involvement destruction of habitat. Plastics, trash, PCBs, fishing debris, heavy metals, and toxins all can cause physical damage to Steller sea lions, in some cases leading to extensive physiological damage, reducing reproductive and natality rates within populations. The 2008 Steller Sea Lion recovery plan is vague at best, suggesting that population trends continue to be observed and researched, and that implementation plans be developed, but even in 2019 not all rookeries were being observed, with the Aleutian Islands only being observed on odd numbered years despite the fact that rookeries west of the Samalga Pass have been consistently decreasing in pup numbers (NOAA Fisheries, 2019). Buffer zones around rookeries should be expanded more than three miles to allow Steller sea lions more prey options, and industries such as plastic production, landfills, and mining should be moved inward so that the possibility of waste runoff directly into oceans is mitigated and reduced and will hopefully decrease the overall concentrations of toxins and heavy metals currently found in marine fish and predators. The closer the ocean and its ecosystem returns to aa healthy balance, and the more humans can take actions against our use of it as an endless trashcan or endless food supply, destroying habitat and always outcompeting Steller sea lions, the more populations will recover.

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